financial data which are sent on an up to the minute basis. Other industries which have a significant demand for international communications are the airline industry, news services, and manufacturing companies with large European operations. Second, as new technology develops which permits more sophisticated voice and data offerings, demand for further telecommunications services is likely to grow.

56. Expected growth in a market typically encourages new entry. However, without a significant increase in competition in the facilities provision for North Atlantic telecommunications, market forces and entry are unlikely to create the full benefits of which they are capable. PTAT will be able to provide the needed increase in competition. PTAT's planned capacity would add 18,000 voice-grade circuits to the North Atlantic market in 1990, or 38 percent of the total. The combined share of AT&T and Comsat would decrease from 85 percent without PTAT to 52 percent with PTAT. PTAT will initially sell or lease capacity on a bulk, private line basis. With the entry of PTAT service providers will have another source of North Atlantic capacity. Prices are likely to fall and demand increase. On the basis of projected prices for PTAT DS-2 circuits, its price for a DS-1 (T-1) equivalent circuit would be 30 - 50 percent lower than the comparable price for AT&T's T-1 service on TAT-8. ("PTAT1 Pricing Effective February 1, 1987," PTAT Presentation, February 1987.) This decrease in facilities price will be passed on to businesses and consumers. Resellers of the capacity will compete with AT&T in the international interexchange market and benefit consumers and businesses who use less than DS-1 capacity.

57. Thus, PTAT entry will increase competition in North Atlantic telecommunications. The situation is likely to change from the current situation of only marginal competition to AT&T to much more effective competition. As the FCC recently found in its approval of the PTAT transfer of control:

> . . .NYNEX Development's proposed acquisition of Tel-Optik [PTAT] will promote competition in transatlantic communications, provide users with new facility and ownership options and generally advance U.S. interests. (Tel-Optik Order, p. 2)

Indeed, the immediate price reductions which will occur upon PTAT's entry will have significant benefits both for US business and consumers. As US businesses compete on a more international basis, the benefit of lower priced international telecommunications is likely to be substantial.

J. A. Hausman

Jerry A. Hausman

Sworn to before me this 29th day of April, 1987

Anne A. Pomness

Notary Public

Commission Expires July 30, 1993

EXHIBITS

SWITCHED AND SPECIAL ACCESS RATES

I. Switched Access

	Originating	Terminating
	--------(Dollars Per Minute)-------	
	(1)	(2)
MTS	$0.0492	$0.0770
WATS	$0.0337	$0.0770

II. Dedicated Access

	Dollars Per Month
NY Telephone DS-1 (2 Miles)	$1,062
NY Telephone DS-1 (1 Mile)	1,009
NY Telephone Single Line (2 Miles)	95
NY Telephone Single Line (1 Mile)	86
Private Microwave (DS-1)	985

Sources and Notes

1) Switched access rates are from New York Telephone's interstate access tariff.
2) Special access rates are calculated from New York Telephone's interstate special access tariff.
3) Private microwave costs are presented in Charles L. Jackson's April 15, 1987 report.

BREAKEVEN POINTS BY SWITCHED SERVICE TYPE AND NONSWITCHED ALTERNATIVES

	Telco Special (2 Mile) (1)	Telco Special (1 Mile) (2)	Private Microwave (3)
MTS			
Originating	21,585	20,514	20,018
Terminating	13,792	13,108	12,790
Out WATS			
Originating	23,830	22,266	21,541
Terminating	13,792	13,108	12,790
In WATS			
Originating	13,792	13,108	12,790
Terminating	23,830	22,266	21,541

Sources and Notes

1) The MTS and Out WATS terminating breakeven points and the In WATS originating breakeven points are estimated by:
   Breakeven Point = Dedicated Access Rate/.077
2) The originating MTS breakeven points are estimated by:
   Breakeven Point = Dedicated Access Rate/.0492.
3) The originating Out WATS and terminating In WATS breakeven points are estimated by: Breakeven Point =
   (Dedicated Access Price - 28.77 x WATS Lines)/.0337
   Dedicated access would result in savings of the 28.77 monthly per line access charge for WATS. At one percent blocking and demands around 20,000 minutes per month, 9 WATS lines would be saved.
4) The rates for switched and dedicated access services are presented in Exhibit 1.

SHARE OF TOP 400 CUSTOMER INTERLATA TOLL USAGE ON TELEPORT'S CURRENT ROUTES

	MTS Minutes (1)	WATS Minutes (2)	Total (3)
Usage Per Month by Top 400 Locations			
Total	13,331,800	19,063,600	32,395,400
On Current Teleport Route	8,900,984	12,594,640	21,495,624
Percent on Teleport Route	66.77%	66.07%	66.35%
Usage for All Manhattan Business Customers	61,959,952	58,409,592	120,369,544
Top 400 Location Usage/Manhattan Business Total	21.52%	32.64%	26.91%
Adjusted Top 400 Usage/Manhattan Business Total	23.79%	40.03%	31.50%
Top 400 Location Usage On Teleport Routes/Manhattan Business Total	14.37%	21.56%	17.86%
Adjusted Top 400 Location Usage On Teleport Routes/Manhattan Business Total	15.89%	26.44%	20.90%

Sources and Notes

Usage data were proved by NYNEX Service Corporation.

Adjusted Top 400 Customer Location Usage is derived by dividing top 400 customer usage by the percent of usage for which we were able to obtain addresses for our sample of 500 customers. The percents were calculated as shown below:

Usage for All Locations	MTS	WATS	Total
Of Top 500 Customers	20,176,775	25,773,018	45,949,793
With Addresses Available	18,245,716	21,014,778	39,260,494
Percent of Usage With Addresses Available	90.43%	81.54%	85.44%

VITA

CURRICULUM VITAE January 1987

JERRY A. HAUSMAN

Date of Birth: May 5, 1946

Marital Status: Married, two children

Citizenship: U.S.

SSAN: 235-70-2864

Degrees:

B.A. (Summa cum Laude), Brown University, 1968
B. Phil., Oxford University, 1972
D. Phil., Oxford University, 1973

Thesis:

A Theoretical and Empirical Study of Vintage Investment and Production in Great Britain (Oxford University, 1973)

Fellowships, Honors, Awards:

Phi Beta Kappa
Marshall Scholar at Oxford, 1970-1972
Scholarship at Nuffield College, Oxford, 1971-1972
Fellow of Econometric Society, 1979-
Frisch Medal of the Econometric Society, 1980
Fisher-Schultz Lecture for the Econometric Society, 1982
John Bates Clark Medal of the American Economic Association, 1985

Research and Teaching Interests:

Econometrics
Microeconomics
Public Finance

Positions:

1968-1970	U.S. Army, Corps of Engineers, Anchorage Alaska
1972-1973	Visiting Scholar, Department of Economics, MIT
1973-1976	Assistant Professor, Department of Economics, MIT
1976-1979	Associate Professor, Department of Economics, MIT
1979-	Professor, Department of Economics
(1982-1983)	Visiting Professor, Department of Economics, Harvard
(1986-1987)	Visiting Professor, Harvard Business School

Other Professional Activities:

Associate Editor, Bell Journal of Economics, 1974-1983
Associate Editor, Rand Journal of Economics, 1984-
Associate Editor, Econometrica, 1978-1986
Reviewer, Mathematical Reviews, 1978-1980
American Editor, Review of Economic Studies, 1979-82
Associate Editor, Journal of Public Economics, 1982-
Associate Editor, Journal of Applied Econometrics, 1985-
Member of MIT Energy Laboratory Policy Research Group, 1973-
Research Associate, National Bureau of Economic Research, 1979-
Member, American Statistical Association Committee on Energy Statistics, 1981-1984
Special Witness (Master) for the Honorable John R. Bartels, U.S. District Court for the Eastern District of New York in Carter vs. Newsday, Inc., 1981-82
Member of Governor's Advisory Council (Massachusetts) for Revenue and Taxation, 1984-
Member, Committee on National Statistics, 1985-

Publications:

I. Econometrics:

"Minimum Mean Square Estimators and Robust Regression." Oxford Bulletin of Statistics (April 1974).

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Attachment 1

High Capacity Transmission Alternatives in Lower Manhattan

by
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April 15, 1987

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TABLE OF CONTENTS

High Capacity Transmission Alternatives in Lower Manhattan

Introduction and Overview

This report looks at the cost and availability of facilities-based alternatives to the high capacity (Hi-Cap) digital services offered by New York Telephone in Manhattan. We look at the cost of carrying high-capacity telecommunications between two locations, for example, a large customer and an interexchange carrier's point of presence (POP), separated by distances of up to a few miles in lower Manhattan (below 59th street). We consider two technologies -- short-haul microwave and fiber optics. Both technologies appear to be widely used today in Manhattan for point-to-point communications. Based upon both this current use, as well as the technical and cost characteristics of the technologies, we conclude that both technologies appear to offer reasonable options throughout most of lower Manhattan. Neither spectrum congestion nor a lack of duct availability prohibit further use of these technologies in Manhattan. Similarly, the cost of these alternatives appears to be competitive with the cost of high-capacity alternatives which we have seen in other communities.

Terminology

By high-capacity digital services we mean those digital transmission services carrying more than one million bits per second. For comparison, when an ordinary telephone circuit is used to carry a data signal, the data rate usually falls in the range of 1,200 to 9,600 bits per second, with 1,200 or 2,400 bits per second being the most common data rates. When a voice signal is digitized and sent as a data stream, 64,000 bits per second are normally required to carry the voice signal. Thus, one million bits per second represents the data from hundreds -- perhaps thousands -- of data terminals or from about 16 voice channels.

The communications industry in North America has standardized on a few specific data rates for voice and data communications at rates exceeding one million bits per second. Two widely used standards are the DS1 rate of 1.544 million bits per second (Mbps) and the DS3 rate of 44.736 Mbps. A third standard, less widely used but still sometimes referred to, is the DS2 rate of 6.312 Mbps. A DS1 channel can carry 24 digitized voice channels, a DS2 channel can carry 96 digitized voice channels, and a DS3 channel can carry 678 digitized voice channels. Thus, a DS2 is the size of four DS1s, and a DS3 is the size of 28 DS1s. (Note that the data rates are not exact multiples. For example, 1.544*4=6.176; not 6.312. This slight difference is due to the need for additional bits for framing the multiplexed signals). The table below summarizes these relationships.

North American Standard High Capacity Data Rates

Rate	Data Rate (Mbps)	Equivalent Voice Circuits
DS1	1.544	24
DS2	6.312	96
DS3	45.736	672

Today, many private branch exchanges (PBXs) and computers can connect directly to communications lines operating at the DS1 rate. Multiplexing equipment is available at reasonable cost to combine multiple DS1s to the DS2 format or to the DS3 format. DS1s and multiple DS1s have become a primary building block for large corporate networks. See, for example, the article **Ford consolidates nets on packet-switched T-1** on page two of the April 13, 1987 issue of Network World.

The DS1 rate is also frequently referred to as a T-1 rate, a T-1 line, or a T-1 signal. This terminology grows out of the history of the industry and, while sometimes confusing, should be recognized as a common usage.

The wide use of these standard rates in North America makes it natural to focus on transmission alternatives at these rates to understand the market for high-capacity alternatives to New York Telephone's services. Further, we understand that New York Telephone's own high-capacity offerings also operate at the DS1 and DS3 rates.

Technologies Considered

This study considers only the fiber optic and microwave facilities transmission alternatives. Each of these technologies has the capacity to carry DS1, DS2 or DS3 signals at reasonable costs. We considered other transmission technologies but quickly eliminated them as too costly. Wire cable is capable of carrying signals at the DS1 or DS2 rate. However, this technology requires active electronics located about every 6,000 feet along the cable run. Such electronics impose significant maintenance expense and degrade reliability. There are no significant cost advantages in installing wire cable rather than fiber optic cable. Thus, fiber optic cable appears to economically dominate wire cable at the high-capacity data rates. Similar considerations of cost and reliability arise when comparing the use of fiber and coaxial cable for point-to-point use. Coaxial cable has some advantages in certain multi-point applications, but we are not considering such systems in this report. Similarly, we considered the use of satellites. However, a quick calculation shows that a satellite is more expensive[1] than short-haul microwave for carrying a DS1 signal a few miles and would be prohibitively expensive for carrying a DS3 signal.

Overview

The discussion below considers both the technical feasibility and the cost of using fiber optic cable and microwave. First we look at fiber optic cable and show that duct space is available for routing in Manhattan (although some specific routes are congested) and then develop a cost model which allows the reader to compare the costs of a dedicated fiber system with the monthly costs of a service obtained from a carrier.

Second, we consider microwave and show that, while many firms and carriers use microwave for short-haul communications in lower Manhattan, there is still substantial opportunity to fit in new microwave links among the existing links. We then develop a cost model -- similar to the cost model for fiber optic cable -- which allows us to compare the costs of a microwave system with the monthly costs of service from a carrier.

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[1] If we assume that a Ku band transponder costs two million dollars per year (roughly market price today) and that a DS1 signal requires three percent of the transponder, then the satellite segment for a DS1 signal would cost ($2,000,000*0.03)/12 = $5,000 per month. This does not include the cost of the required earth stations.

Third, we present the results of the cost models in tabular form for easy comparison with the cost of other transmission alternatives.

Finally, we summarize our results and offer our conclusions.

Using Optical Fiber Facilities in Lower Manhattan

Overview of Fiber Technology

Optical fiber is an excellent technology for carrying high-capacity signals. Fiber optic communications systems consist of two essential components -- the fiber optic cable and the opto-electronics which transmit and receive the optical signals over the fibers. Optical fiber cable consists of tiny optical fibers enclosed by plastic and reinforcing fibers which protect it from the elements, abrasion, sharp bends, and other harmful environmental effects. Optical fiber cable is lighter and more flexible than traditional telecommunications cable or coaxial cable. Thus, it is easier to handle and install.

The opto-electronic units which generate the light pulses that travel over the fiber are usually called modems, since they modulate and demodulate the light signals. However, such units are sometimes called multiplexers as they frequently include a multiplexing function as well as the modem functions. These units are small and light. A unit capable of transmitting and receiving a DS1 signal is only a few inches in any dimension and weighs about two pounds.

Advantages of Fiber Optics

High-capacity is a primary advantage of fiber optics. Fiber systems can carry up to billions of bits per second. A fiber system carrying a DS1 signal or a DS3 signal is carrying only a small fraction of the theoretical capacity of the fiber[2]. Thus there is considerable margin between the theoretical capacity and the needed capacity which allows cost-saving simplifications in the transmission equipment.

Optical fiber is normally able to carry signals several miles without amplification along the way. This is in marked contrast to wire cable or coaxial cable which require amplification of high-capacity signals about every mile or so.

Optical fiber cable costs about $1.00 per foot. The specific cost varies with the number of fibers in the cable, the environmental conditions expected, and whether the

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[2] For precision, this statement could be qualified by reference to fiber dispersion, single-mode versus multi-mode, and link distance. But, generally speaking, an off-the-shelf fiber can carry hundreds of millions of bits per second a few miles. The best of fibers on the market can carry billions of bits per second 10 or 20 miles. Notice that these quantities are orders of magnitude greater than the 1.5 to 45 millions of bits per second of a "high-capacity" circuit.

cable has a built-in messenger (support) wire, etc. It is possible to obtain optical fiber cable that is totally electrically insulating and therefore can be installed safely in ducts carrying electric power or can be lashed to electrical power lines.

The modems needed to convert electrical signals to optical signals, to launch those optical signals on the cable, and to perform the inverse operations are relatively inexpensive. A short-range DS1 and DS2 modems sell for about $700. A DS3 modem (which also contains the multiplexing equipment needed to interface with DS1 lines) sells for about $25,000.

Duct Space Availability

Ducts[3] in Manhattan are provided by the Empire City Subway Company. This firm was created in the late nineteenth century to own the ducts in New York City carrying low voltage communications wires. The firm itself is owned by New York Telephone, but it provides duct space and services to all entities who have authority from the City to use the municipal duct rights-of-way. The primary entities using Empire City Subway's duct system are New York Telephone, Western Union, the cable television companies, Teleport, New York City itself, and AT&T. A number of other smaller entities are also tenants in the Empire City Subway system. While New York Telephone and Western Union have been tenants of the system since the nineteenth century, other tenants -- such as AT&T, Teleport, and most of the smaller entities -- have become tenants in the last decade.

Individual firms can become Empire City tenants by applying to the municipal Board of Franchises for a specific franchise. Consequently, each franchise application reflects the particular route a firm wishes to occupy. Franchise approval takes six to 15 months.

Empire City Subway tells us that in much of downtown and midtown the ducts are extremely congested right now. There are many buildings with no vacant conduit in front of them. In such cases, building access must be accomplished via the sides. However, Empire City feels that the vast majority of buildings can be accessed and

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[3] The information on duct availability and usage in Manhattan was obtained from an interview with Mr. Ed Stegeman of Empire City Subway on March 26, 1987.

connected with conduit routes -- although such routes may be circuitous in order to avoid congested ducts. The fiber optic cost model presented below assumes that the actual route is 1.4 times the direct distance. This corresponds to a route which follows the road grid while the direct route crosses over the middle of the block.

Empire City charges $6,276 per mile per year for rental of four inch diameter conduit, $4,512 for rental of three inch diameter conduit, and $3,924 for rental of 2.5 inch diameter conduit. In those cases where building access from the conduit does not exist, a reasonable cost for establishing building access is $150 per foot from the conduit to the building.

Fiber Optic Cost Model

We have developed the following model for the cost of dedicated, point-to-point, fiber optic facilities in lower Manhattan.

Modems:

DS1 rate:	$689/modem (two required per link)
Product:	Lee's Data Communications, Model 1024
Range:	Up to six route miles
Data Source:	Lee's Data Price list dated Jan., 1987
DS2 rate:	$689/modem (two required per link)
Product:	Lee's Data Communications, Model 1023
Range:	Up to three miles
Data Source:	Lee's Data Price list dated Jan., 1987
DS3 rate:	$24,200 (two required per link)
Product:	Rockwell DML-45
Range:	Up to 30 miles
Data Source:	Collins Budget Estimate Guide (6/15/84)

Fiber:

Short-Haul:	$2.45 per meter
Long-Haul:	$3.00 per meter

Duct Rental:	$6,276 per mile per year
Installation:	$3,000 per mile

Operations and Maintenance (O&M) costs:

Duct access when route does not go to exiting entrance facility:
$7,500 (assume 50 feet at $150 per foot)

An O&M allowance of one percent per month of the hardware cost is included, except for the cost of fiber cable. An O&M allowance of 0.25 percent per month is included for the cost of the fiber cable.